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A Metallographic Study of Primitive Copper Work.

John A. Alley

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A METALLOGRAPHIC STUDY
OF PRIMITIVE COPPER WORK

by
John A. Alley

A Thesis
Submitted to the Department of Metallurgy
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Metallurgical Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA.
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INTRODUCTION

The field of archaeology and that of metallurgy appear to be widely separated and in no way related. Work done in recent years, however, tends to show that, in many ways, the metallurgist can supplement and enhance the information gained by the archaeologist, at least in regard to those objects which have been made of metal.

A study has been made of the effect of extremely long periods of corrosion on the structure of bronze and copper. 1 A process has been worked out for the restoration of corroded metal objects to their original state by electrolytic methods. 2 A recent investigation in the field of archaeology and metallurgy has been made at the Montana School of Mines. 3 Several copper artifacts of primitive origin were studied to determine the methods used in their manufacture. Due to the great interest with which this paper was received, an investigation was started along similar lines. Through the courtesy of various museums and collectors, specimens were obtained for use in this study.

As is well known, the grain structure of metals and alloys reveals many secrets to the trained eye of the metallographer.

Knowledge as to the composition, method of working, heat-treatment used, and other metallurgical aspects, can be determined by reference to specimens whose history of manufacture is known or by knowledge already obtained with respect to the effect of certain treatment on the structure of various metals or alloys.

In the case of copper much is known about these effects.

Native copper, so-called, is copper which has been precipitated in cracks and crevices in the rock. This copper is perfectly homogeneous, weathers out in fairly large nuggets, and is the material from which were made the copper implements of ancient man.

A polished and etched section of native copper shows no grain structure when examined under the microscope. If a piece of native copper is cold-worked, either by hammering or rolling, the result is the same. Therefore, any copper artifact which, in a polished section, shows a plain bright field, has been cold-worked. However, if the cold-worked object is heated after it has been worked, a polished section under the microscope will reveal the grain structure. If the heating has been slight, the grains will be quite small, irregular in shape, and of various sizes. If, however, the object has been subjected to a thorough heating at a fairly high temperature, which is annealing, the grains will be equiaxed and of the same size, although still fine-grained. This is known as recrystallization and is always produced by annealing copper which has been mechanically work-
ed. Further heating produces the phenomenon known as grain growth, in which the grains absorb one another, forming larger grains.

If copper is hot-worked, the grains are of good size, although it will show the other properties exhibited by the cold-worked copper, i.e., distorted grains of different sizes. Annealing the hot-worked copper will produce the same effects as in the case of cold-worked copper.

Twinning will occur in all copper which has been mechanically worked and heat treated.

This and other evidence, such as slip-bands, which indicate a low finishing temperature, furnish the metallographer with his criteria for determining the method used in the manufacture of an artifact. The size of the grains, the equality of size, and the amount of equiaxing tell him whether the object has been hot-worked, and if so, the approximate temperature used, and whether the annealing, if any, was poor or good, and at what temperature it was accomplished.

POLISHING AND ETCHING OF SPECIMENS

Specimens are prepared for microscopic examination by grinding and polishing a section large enough to form a field under the microscope.

A plane surface was first secured by filing or with an emery wheel copiously supplied with water. This surface was then ground to smoothness by successive treatments on No's 0, 00, 000, and 0000 emery paper. Polishing on canvas, using levigated rouge as an abrasive; followed by polishing on felt, using levigated alumina as an abrasive; and a final polishing on clean,
wet felt, completed the operation.

Etching was done with an etchant composed of one part of ammonium hydroxide and one part of hydrogen peroxide. The specimen was etched by swabbing, washed with water, and dried with alcohol.

MICROSCOPIC EXAMINATION

The prepared specimen was mounted in a specimen holder and examined under the microscope, using a magnification which would reveal the structure in sufficient detail. The majority of the specimens were examined under a magnification of 100 times.

Sketches and photomicrographs were made of each section, the latter not being employed except in such cases where the structure was especially significant.

From the examination itself, the sketches, and the photomicrographs, conclusions were drawn as to the methods which had been used in the making of each specimen.
SPECIMENS STUDIED

Laboratory number: 1.
Catalog Number: 92442.

Object: Copper Tube.
Location of Find: Fond du Lac County, Wisconsin.
Donor: Peabody Museum.
Features: Quite fine-grained. Shows twinning. Small amount of grain growth indicated.
Conclusions: Cold work followed by a small amount of heating.

Laboratory Number: 2.
Catalog Number: 653

Object: Small chisel.
Location of Find: Wisconsin.
Donor: Logan Museum, Beloit College, Beloit, Wisconsin.
Features: On first etching, showed many slip-bands. Shows twinning. Grains are of different sizes and have unequal axes.
Conclusions: Hot work with a low finishing temperature.
Fig. 1-Specimen 1. X 275.
Fig. 2-Specimen 2. X 275.
Fig. 3-Specimen 4. X 275.
Fig. 4-Specimen 5. X 275.
Laboratory Number: 3.
Catalog Number: 11605.

Object: Copper knife.
Location of Find: Near Iola, Waupeca County, Wisconsin. Surface find.
Donor: Milwaukee Public Museum, Milwaukee, Wisconsin.
Features: Twinning, distorted grains.
Conclusions: Hot work with a low finishing temperature.

Laboratory Number: 4.
Catalog Number: 621.

Object: Copper chisel.
Location of Find: Wisconsin.
Donor: Logan Museum.
Features: Twinning, different size grains, unequal axes.
Conclusions: Hot work at a fairly low temperature.

Laboratory Number: 5.
Catalog Number: 1898.

Object: Spear-point.
Location of Find: Chilton, Calumet County, Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, different size grains, unequal axes.
Conclusions: Hot work at quite a high temperature.
Laboratory Number: 6.
Catalog Number: 11585.

Object: Spear-point.
Location of Find: Conrad farm, Hartford, Washington County, Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, different size grains, unequal axes.
Conclusions: Hot work at quite a high temperature.

Fig. 6. 64X

Laboratory Number: 7.
Catalog Number: 2079.

Object: Spear-point.
Location of Find: Rhine, Sheboygan County, Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, different size grains, unequal axes.
Conclusions: Hot work at quite a high temperature

Fig. 7. 64X

Laboratory Number: 8.
Catalog Number: 2076.

Object: Spear-point.
Location of Find: Rhine, Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, small equiaxed grains of uniform size.
Conclusions: Hot work at good temperature

Fig. 8. 64X
followed by good annealing at a low temperature.

Laboratory Number: 9.
Catalog Number: 2083.

Object: Scraper.
Location of Find: Rhine, Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, varied grain size.
Conclusions: Hot work at high temperature followed by imperfect annealing at a low temperature.

Laboratory Number: 10.
Catalog Number: 640.

Object: Socket Point.
Location of Find: Concord, Wisconsin.
Donor: Logan Museum.
Features: Twinning, large equiaxed grains.
Conclusions: Hot work followed by good annealing, both at high temperatures.
Laboratory Number: 11.
Catalog Number: 94032.
Object: Copper implement.
Location of Find: Wisconsin - probably.
Donor: Peabody Museum.
Features: Twinning, large equiaxed grains.
Conclusions: Hot work followed by good annealing, both at quite a high temperature.

Laboratory Number: 12.
Catalog Number: 11596.
Object: Socket point.
Location of Find: Lake La Belle, Waukesha County, Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, large equiaxed grains.
Conclusions: Hot work followed by good annealing. Possibility of a small amount of hot work after annealing.

Laboratory Number: 13.
Catalog Number: 626.
Object: Leaf blade.
Location of Find: Wisconsin.
Donor: Logan Museum.
Features: Twinning, quite large grains.
Edges show smaller grain size than the interior.
Conclusions: Hot work followed by good ab-
PLATE II

PHOTOMICROGRAPHS

Fig. 5-Specimen 10. X 275.
Fig. 6-Specimen 12. X 275.
Fig. 7-Specimen 15. X 275.
Fig. 8-Specimen 16. X 275.
nealing. Edges have been mechanically worked after annealing.

Laboratory Number: 14.
Catalog Number: 2226.

Object: Axe-head.
Location of Find: Wisconsin. Surface find.
Donor: Milwaukee Public Museum.
Features: Twinning, large grains.
Conclusions: Hot work followed by good annealing, both at a high temperature.

Fig. 14.
25X

Laboratory Number: 15.
Catalog Number: 440.

Object: Small point-socket type.
Location of Find: Wisconsin.
Donor: Logan Museum.
Features: Fine-grained structure, some twinning.
Conclusions: Either cold work followed by a small amount of heating or has been cast.
Laboratory Number: 16.
Catalog Number: None.
Object: Copper Implement.
Location of Find: Hahn's Field, Madisonville, Ohio.
Donor: Peabody Museum.
Features: Twinning, distorted grains.
Conclusions: Hot work with a low finishing temperature.

Laboratory Number: 17.
Catalog Number: None.
Object: Arrow-head.
Location of Find: Montana.
Donor: P. A. Smith, Butte, Montana.
Features: Twinning, small grain size, Shows some equiaxed grains.
Conclusions: Cold work followed by a small amount of heating.

Laboratory Number: 18.
Catalog Number: None.
Object: Fragment of an ornament.
Location of Find: Texas.
Donor: ?
Features: Twinning, different size grains, unequal axes.
Conclusions: Hot work at a good temperature.
Fig. 9-Specimen 18. X 275.

Fig. 10-Specimen 19. X 275.

Fig. 11-Specimen 20. X 275.
Laboratory Number: 19.
Catalog Number: None.

Object: Spear-point, socket type.
Location of Find: Near Superior, Minnesota.
Donor: Robert Dickey, Baker, Minnesota.
Features: Twinning, equiaxed grains.
Conclusions: Hot work followed by good annealing at a low temperature.

Fig. 19.
64X

Laboratory Number: 20.
Catalog Number: 4401-22.

Object: Copper head.
Location of Find: Medicine Creek 5 (Dick site), Curtis, Nebraska.
Donor: Nebraska State Historical Society, Lincoln, Nebraska.
Features: Twinning, unequal axes, small grains of different sizes.
Conclusions: Cold work followed by a small amount of heating.

Laboratory Number: 21.
Catalog Number: None.

Object: Fragment of an ornament.
Location of Find: Indian burial pit, Randolph County, North Carolina. (Keyaunee site)

Fig. 21.
100X
Features: No structure evident.
Conclusions: Cold work.
All specimens one-half actual size.

Fig. 1-Specimens 5, 4, 3, 2, 1.
Fig. 2-Specimens 9, 8, 7, 6.
Fig. 3-Specimens 13, 12, 11, 10.
Fig. 4-Specimens 17, 16, 15, 14.
Fig. 5—Specimens 20, 19, 18.
CONCLUSIONS

It may be seen that the majority of the specimens examined in the course of this investigation show distinct evidence of having been subjected to heating in some stage of their manufacture.

Whether or not this was accidental or whether ancient man had discovered the improved qualities that heat treatment imparted to his product is not a question the metallurgist is prepared or qualified to answer. Certainly the predominance of specimens which have, without doubt, been hot-worked, would tend to show that man realized heat-softened metal was much more easily shaped than that which had had no preliminary heating.

The evidence of annealing, while not quite as predominant as that of hot work, is still sufficiently strong enough to discount its being accidental. It is possible that the object was inadvertently dropped into a fire after having been made, but its owner would scarcely have left it there for any length of time, least of all time enough for annealing to occur.

It has been suggested that forest fires, which primeval America had in profusion, may have caused the annealing. Since most of the specimens examined came from Wisconsin, a heavily-forested region, this theory may have some basis in fact. It can only be proved or disproved, however, by a study of specimens found in burial pits or mounds, or from regions where there have been no trees, such conditions hardly allowing for annealing by forest fires.

Thus, metallurgy supplies the facts, archaeology must carry on from there. It does not seem entirely unreasonable to assume that man discovered early the effects of heat treatment. His in-
 intelligence, as shown by his accomplishments in other lines, was
certainly good enough to lend credence to this theory.

Examination of more specimens representing a wider area
than was possible in this work, will I think, provide the answer.
ACKNOWLEDGEMENTS

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